MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 3, 2017/2018

ETN4106 – OPTOELECTRONICS AND OPTICAL COMMUNICATIONS
(All sections/Groups)

30 MAY 2018
9:00 a.m. – 11:00 a.m.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 7 pages with 4 Questions only.
2. Answer **ALL** questions. The distribution of the marks for each question is given.
3. Please print all your answers in the Answer Booklet provided.

Question 1 (25 marks)

(a) Describe the term acceptance angle. Support your answer with a diagram. [3 marks]

(b) A graded-index multimode fiber with a numerical aperture of 0.4 has a core diameter of 60 μm. Given that the characteristic index profile α = 1.95, determine:

(i) The cut-off value of normalized frequency, V_c. [2 marks]

(ii) The cut-off wavelength for the fiber to operate as a single mode fiber. [2 marks]

(iii) The number of guided modes propagating in the fiber when the wavelength of light is 1550 nm. [4 marks]

(iv) The acceptance angle when the fiber is placed in water. Assume that the refractive index of water is 1.33. [2 marks]

(v) The core refractive index, if the relative refractive index difference is 1.35 %. [2 marks]

(c) Describe the following light attenuation mechanisms.

(i) Intrinsic absorption [2 marks]

(ii) Extrinsic absorption [2 marks]

(d) Suggest TWO (2) ways to reduce macrobending losses in optical fiber. [2 marks]

(e) State TWO (2) types of linear scatterings and their causes. [4 marks]

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Question 2 (25 marks)

(a) The optical sources used in optical fiber communication systems are laser diodes and light emitting diodes (LEDs).

(i) Describe the stimulated emission process which gives laser its coherent radiation. Your answer should include description of the photons emitted. [4 marks]

(ii) LEDs are commonly used in a local area network. Give TWO (2) reasons for this. [4 marks]

(b) Compare the photon absorption process in direct bandgap and indirect bandgap semiconductors. [4 marks]

(c) Calculate the ratio of the threshold current densities at 30 °C and 90 °C for an injection laser with its threshold temperature coefficient, T_o = 160 K [Hint: The ratio of the threshold current densities is $\frac{J_{th}(90^oC)}{J_{th}(30^oC)}$]. [5 marks]

(d) The quantum efficiency of a photodiode is 70% when photons having an energy of 2×10^{-19} J are incident upon it.

(i) With the help of a suitable equation, define quantum efficiency. [2 marks]

(ii) Why is the quantum efficiency of a photodiode generally less than unity? [2 marks]

(iii) Calculate the responsivity of the photodiode. [2 marks]

(iv) Calculate the incident optical power required to obtain a photocurrent of 8 μA. [2 marks]

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Question 3 (25 marks)

(a) Do optical amplifiers provide better performance over regenerative repeaters which require optoelectronic devices and electronic circuits? Give TWO (2) reasons to support your answer. [5 marks]

(b) Illustrate TWO (2) applications of optical amplifiers that can be used to increase the transmission distance in an optical network. [4 marks]

(c) Erbium doped fiber amplifiers (EDFAs) are widely used in optical communication networks.

(i) Describe TWO (2) ways to attain population inversion in an EDFA. [4 marks]

(ii) What is the dominant noise generated in an EDFA? [2 marks]

(iii) An EDFA is being pumped at 980 nm with a 20 mW pump power. If the gain at 1550 nm is 25 dB, calculate the maximum input power and output power. [4 marks]

(d) A bit stream of '10110' is modulated at the transmitter of an optical communication system.

(i) Draw the modulated carrier waveform if amplitude shift keying (ASK) scheme is used. [2 marks]

(ii) Draw the modulated carrier waveform if frequency shift keying (FSK) scheme is used. [2 marks]

(iii) Draw the modulated carrier waveform if phase shift keying (PSK) scheme is used. [2 marks]

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Question 4 (25 marks)

(a) Your company recently won a tender to install optical fiber network facilities in a new university campus. The system requirement is an optical link that is able to support signal transmission at a bit rate of 100 Mbps and a link that can support a maximum transmission distance of 2 km. The system should be designed in the most cost-effective way using only the components listed in Table 4 (a).

Optical Component	Transmit power	Receiver sensitivity	Loss
Laser diode with central wavelength at 1550 nm	0 dBm	-	-
LED with central wavelength at 850 nm	-13 dBm	-	-
p-i-n photodiode	-	-32.8 dBm	-
Avalanche photodiode	-	-41.4 dBm	-
Single mode fiber	-	-	1.3 dB/km at 850 nm 0.4 dB/km at 1310 nm 0.3 dB/km at 1550 nm
Step-index multimode fiber	-	-	4 dB/km at 850 nm
Graded-index multimode fiber	-	-	2.5dB/km at 850 nm 0.8dB/km at 1300 nm
Source coupling loss	-	-	0.1 dB
Detector coupling loss	-	-	0.1 dB
Splice loss	-	-	0.03 dB

Table 4 (a)

Continued ....

Question 4 (continued)

(i) Propose a suitable operating wavelength for your system (850 nm, 1310 nm or 1550 nm). Justify your choice. [4 marks]

(ii) Propose a suitable fiber type for your design. Justify your answer. [4 marks]

(iii) Propose a suitable optical source for your design. Justify your answer. [4 marks]

(iv) Propose a suitable optical detector for your design. Justify your answer [4 marks]

(v) Based on your answer in Q4 (ii), calculate the fiber cable loss for the 2 km fiber. [2 marks]

(vi) Calculate the total channel loss of one link (2 km fiber length). Assume that splicing is only needed to connect the fiber with pigtails at the source and detector. [2 marks]

(vii) Based on your selection in Q4 (iii)-(iv), calculate the power budget. [2 marks]

(viii) Calculate the system margin. Show that your design fulfills the power budget requirement. [3 marks]

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Appendix A

Physical Constants and Units

Constant	Symbol	Value (mks units)
Speed of light in vacuum	c	2.998×10^{8} m/s
Electron charge	e	1.602×10^{-19} C
Boltzmann's constant	k_B	1.38×10^{-23} J/K
Permittivity of free space	ε_0	8.8542×10^{-12} F/m
Permeability of free space	μ_0	$4\pi \times 10^{-7}$ N/A^2
Electron volt	eV	1 eV = 1.602×10^{-19} J
Planck's constant	h	6.626×10^{-34} J·s

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